Stabilization of Gedebage Expansive Soil on Shear Strength Using Vermiculite and Emulsified Asphalt

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ABSTRACT
A construction failure might be caused by so many factors, one of them is the poor properties of the subgrade. A subgrade with low bearing capacity and low shear strength can cause a large settlement. This problem usually occurs in an area where the soil receives too much water. The settlement phenomena can lead to forming a crack on any construction above it. On a sloped area or steep area, high soil shear strength prevents land sliding from occurring. To overcome soil problems mentioned before, stabilization is needed to improve soil's properties. In this research, soil stabilization is done by adding vermiculite to absorb excess moisture content. Silica in vermiculite can also improve soil's poor physical and mechanical behaviour. Meanwhile, the second additive is emulsified asphalt that acts as the adhesive substance to increase particle bonding of the soil. Emulsified asphalt percentage in this research is constant on 8% of the soil's weight, and the vermiculite varies from 3%, 5%, and 7% of the soil's weight. This research used soft soil and aimed to obtain the effect of stabilization mixture on soil's shear strength. Shear strength is a result of triaxial testing to get shear angle value and cohesion value. Shear angle represents the soil's ability to form friction to withstand sliding and the cohesion represents the soil boding for each particle. The expected result from this stabilization is in a certain percentage of emulsified asphalt and vermiculite mixture can strengthen the soil by increasing the shear angle and cohesion of the soil on the triaxial test, so the poor soil characteristic and strength will be improved.

Keywords: *emulsified_asphalt, soft_soil, stabilization, subgrade, vermiculite.*

1. INTRODUCTION

Soil base where the construction stand is called subsoil or subgrade. A subgrade has a really important role in supporting building or any construction on it. Therefore, the soil must have the ability to withstand and distribute the construction itself and other loads that work on it. A poor soil condition with low shear strength and cohesion without any improvement will also affect the quality of the building. The most common problem on that kind of soil is settlement and sliding. To overcome it, a stabilization is needed.

This research is a continuation of previous research which only discussed the soil property index. This research aims to improve soil characteristics by adding vermiculite and emulsified asphalt towards shear strength and cohesion of the soil. Another aim is to find the exact percentage of stabilization mixture to fill the gap from previous researches. The vermiculite acts as an excess water absorber mineral and the emulsified asphalt will act as adhesive material to form particle bonding between soil and vermiculite.

2. LITERATURE REVIEW

Subgrade or subsoil is taking an important role in a construction foundation support system. Unfavorable soil characteristics can leads to construction crack and failure due to settlement and sliding. It can be caused by low particle bonding, extreme slope, excess water, extreme dimension of a slope, and overloading [1]. A settlement may cause the building to be damaged or influencing a building's serviceability of the construction[2] [3]. The main cause is the soil's tendency to be compressible, excessive swelling potential, low level of shear strength, permeability, bearing capacity, and lack of particle bonding on a high water content condition [4], [5]. This poor soil characteristic needs to be improved by doing reinforcement, replacing soil area, or mixing with other strengthening materials [6]. To improve compressibility, bearing capacity, permeability, sensitivity to the fluctuating change of water content, then repair treatment is planned using vermiculite to absorb water. Meanwhile, the asphalt emulsion is chosen as the adhesive agent to the mixture of soil [7][8][9].

Previous research proved that adding 8% of emulsified asphalt may improve soil strength because of its ability to increase particle bond and its chemical substances reaction with soil [7]. Vermiculite is chosen to lower the Index Properties and increase the strength on the optimum addition level on 4% vermiculite [8]. Adding vermiculite and emulsified asphalt is showing improvement toward soil by decreasing the Plasticity Index [10].

2.1 Expansive Soil

Most soft soil or clay contains mostly microscopic and sub-microscopic material. A material named Montmorillonite causes the soil to have a very sensitive characteristic to water. It tends to expand and shrink due to its high water absorption rate. The expansive pressure will damage the construction above the soil and around it [11]. Other minerals that are commonly found are Illite and Kaolinite. A characteristic of soil depends on the percentage of dominant material, at a certain level, it may cause the soil to have really good behaviour or really poor behaviour. An expansive soil has mostly microscopic and sub-microscopic material size (<0.002 mm or 2 microns), and its particle size may vary between >100 mm - <0.001 mm. [4] [12].

The previous research shows that Gedebage soil is classified as soft clay with high plasticity index as shown in table 1. Gedebage soil is also categorized as expansive clay soil from the high PI and physical appearance that expands due to water excess and cracks due to water shrinkage. According to AASHTO, it can be classified as fair to poor subgrade, and according to USCS it can be classified as fat clay or clay with high plasticity (CH) [10].

Table 1. Soft Soil Physical Testing

	Index Properties	Symbol	Unit	Result
1.	Water Content	W	%	50.897
2.	Specific Gravity	Gs	-	2.54
3.	Atterberg Limits			
	Plastic Limit	PL	%	37.32
	Liquid Limit	LL	%	85.41
	Plasticity Index	PI	%	48.09
4.	Activity Level	AC	%	1.05

Where:

V1 = Original Soil
PL = Plastic Limit
LL = Liquid Limit
PI = Plasticity Index
AC = Activity Level

2.2 Vermiculite

Vermiculite is an excess product mineral from a high-temperature heated silica. It is formed by the heating process and it is formed from magnesium aluminum silica. Vermiculite's ability to absorbs excess water is usually used on farming soil, but this also works on construction as well. Its ability can overcome soft soil problems due to excess water content, and its silica content can react with the soil to strengthen it. The mineral properties test by Dupre Mineral Ltd shows that the highest mineral content on vermiculite is SiO (Aluminium Silica), as shown in Table 2 below.

Table 2. Mineral Content in Vermiculite

Mineral	%	Mineral	%	Mineral	%
SiO_2	34,46	Mn_3O_4	0,15	CaO	0,54
MgO	20,96	V_2O_5	<0,05	K_2O	0,29
Al_2O_3	12,79	Cr_2O_3	<0,05	P_2O_3	0,29
Fe_2O_5	8,98	BaO	<0,05	Na_2O	0,07
TiO_2	1,59	ZrO_2	<0,05	ZnO	<0,05
SrO	<0,05	Carbon	0,03	Fluorine	0,44
Source : Dupre Minerals Ltd					

2.3 Emulsified Asphalt

Emulsified asphalt is a form of hard bituminous asphalt dispersion by water and emulsifier agent. It is usually in liquid form at a normal temperature and atmospheric pressure. The emulsifying agent takes the role to emulsify and creating water and particles bonding (The Asphalt Insitute,1992). Based on its setting time, emulsified asphalt is categorized as Rapid Setting (RS), Medium Setting (MS), and Slow Setting (SS). The characteristic details can be shown in Table 3.

The adhesive characteristic of asphalt is used to add more strength to soil especially when the asphalt hardens and forms additional bonding between particles. Emulsified asphalt also can raise soil strength by lowering the Plasticity Index and increasing the unconfined compression (qu) of clayey soil [9]. The optimum percentage to increase soil strength is 8% [7], [9].

Table 3. Emulsified Asphalt Setting Time

Type	Characteristic
RS	- Fast reaction from emulsifier to asphalt - Fast reaction to form bonding with aggregate
MS	- Medium reaction bonding towards course aggregate - Setting time happens after some minutes
SS	- Slow reaction bonding towards any aggregate - High stability, setting time happens after 24 hours

2.4 *Shear Strength*

Among any soil strength parameters, shear strength plays a role in defining the soil's sensitivity towards sliding. Shear strength is a magnitude of shear stress that a soil can hold, formed by friction and pressure that can be defined as shear angle (φ), to create an interlock between soil particles or cohesion (c). Shear strength can also be described as the result of friction and interlocking of particles caused by possibly cementation or bonding of particle contact [13]. Shear angle for sandy soil is higher than the cohesion for sandy soil and vice versa for clayey soil characteristics [14]. Many factors that can affect shear strength are material consistency, mineralogy, grain size distribution, particle shape, void ratio, and features like layers, joints, fissures, and cementation bonding [15]. The pressure needs to be confined or adjusted to change the soil's behaviour. Triaxial is used to stimulate this confining pressure. [16]. The higher the shear strength, the more resistance gained to prevent soil from collapsing.

Triaxial testing is a series of tests to determine the magnitude of soil shear strength. The test is done by applying pressure to the soil cylinder sample from 3 different directions. There are 3 kinds of triaxial testing. They are: 1.) Triaxial Undrained Unconsolidated (UU), 2.) Triaxial Consolidated Undrained (CU), 3.) Triaxial Consolidated Drained (CD). Each kind of testing is used for different purposes on site, as described in Table 4. This research uses Triaxial UU testing for the short-term construction stage so the shear strength can be immediately obtained. The result of the shear angle is also determined by the kind of soil, as can be explained in Table 5.

Table 4. Triaxial Test for Various Specification of Construction

Characteristic	Construction Site	Shear Testing
Cohesive	Short Term (Final Stage Construction)	UU or CU for Undrained Strength with certain level of insitu stress
	Staged Construction	CU for Undrained Strength with certain level of insitu stress
	Long Term Construction	CU with pore pressure measurement or CD with effective shear strength parameter
Granular	Any Kind	Hear strength parameter φ' from site testing or direct shear
Material c- φ	Long Term	CU with pore pressure measurement or CD with effective shear strength

Table 5. Correlation Between Soil Classification and Shear Angle (ϕ)

Soil Classification	φ
Sand Gravel	35°-45°
Gravel	35°-40°
Solid Sand	35°-40°
Loose Sad	30°
Silty Clay	25°-30°
Clay	20°-25°

3. METHODOLOGY

This research is done due to the number of cases of settlement and sliding that lead to construction failure. The initial step of this research is by doing the physical properties of the soil, and after the soil is confirmed to have poor properties, a stabilization is done to improve it. The stabilization is done by mixing the soil with vermiculite and emulsified asphalt. Moreover, in this research SS type of asphalt is used to make the mixing process easier, so the asphalt will harden by the time the soil mixture is perfectly homogenous. After that, researchers also need to obtain the soil's mechanical properties by doing the Undrained Unconsolidated Triaxial Test of the soft soil and stabilized soil. A further explanation is shown in Figure 1.

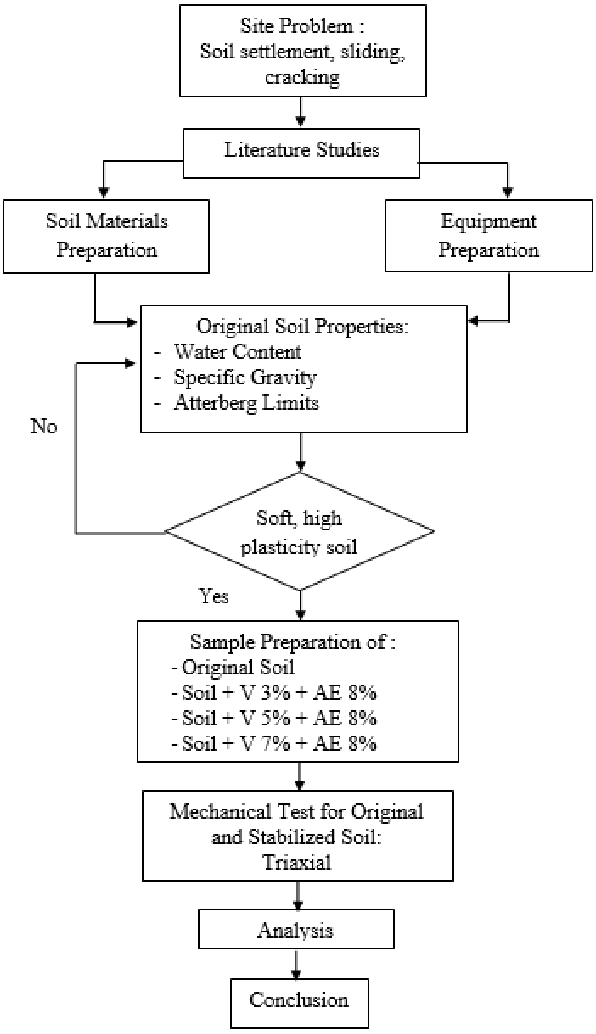

Figure 1 Research Flow Chart

3.1. Index Properties

Index Properties Test is aimed to obtain detailed soil's physical characteristics. The result would show how the soil physically behaves, and it is used to classify the soil's characteristics. This classification is very important to decide what method should be used to overcome the problem and how the construction is built. The step can be done through the test, as shown in Table 6. After the Index Properties are obtained, the stabilization is done by the same testing method but with the addition of stabilization materials.

Table 6. Index Properties Soil Test

No.	Testing Item	Testing Standard
1.	Atterberg Limit Test	ASTM D4318
2.	Specific Gravity Test	ASTM D854
3.	Water Content Test	ASTM D2216
4.	Volume Weight Test	ASTM D2216

3.2. Engineering Properties

This series of the test is aimed to obtain detailed mechanical properties of the soil. The initial step is doing a Compaction Test to obtain the optimum water content the soil can hold to get its maximum strength. The parameter of shear strength and cohesion is obtained by Triaxial Test. Then the stabilization is done using the same testing method and steps, but with stabilization materials.

Table 7. Mechanical Properties Test

No.	Testing Item	Testing Standard
1.	Compaction Test	ASTM D698
2.	Triaxial Test	SNI 03-4813-1998

3. RESULT AND DISCUSSION

The Shear Strength parameter was obtained by doing Triaxial Testing. The method used in this research was adjusted based on the soil's characteristics and construction purposed. Triaxial UU was applied to obtain the shear strength parameter on clay soil for a short-term construction stage. Shear strength result was shown by two kinds of graphic, Stress-Strain graph and Mohr Circle graph. The Mohr Circle was getting bigger and had a higher peak along with the applied load on the test. Collapse occured when the Mohr Circle touched the collapse line.

Gedebage soil is an expansive soil or can be classified as a very poor soft clay. It is confirmed by the previous testing result that shows it has a high Plasticity Index on table 1. This Triaxial Testing also shows the poor quality of soil strength ($\phi < 20°$). The shear angle and cohesion are shown below.

Table 8. Shear Angle and Cohesion Result

	V1	V2	V3	V4
·	17°	18°	20°	17°
c	0,39	0,41	0,45	0,42
S (kg/cm^2) 0,5	1,330	1,480	1,573	1,411
1,0	1,692	1,770	1,900	1,763
1,5	2,108	2,172	2,442	2,165

Where:
V1 = Soft Soil
V2 = Soil + 3% Vermiculite + 8% Emulsified Asphalt
V3 = Soil + 5% Vermiculite + 8% Emulsified Asphalt
V4 = Soil + 7% Vermiculite + 8% Emulsified Asphalt

The soft soil (V1) shows a really low level of shear angle (ϕ), then it slowly increases on the next variation but decreases on the last variation. According to Table 4, the variation V1 can be classified as clay with a poor shear angle. The maximum increasing level is on the variation V3 that shows 20° shear angle or can be classified as clay, which means the soil is improving its shear strength.

From the testing above, the cohesion of every variation also shows increment, which indicates there is increasing soil strength. The level of cohesion represents the soil's particle bonding ability to each other, the lower the cohesion value, the lower the soil's ability to interlock and form a resistance to load and forces. Variation V1 shows the lowest cohesion value. It keeps increasing until V3 and then drops on V4.

The final soil shear strength can be described on the stress strain graphic as shown in Figures 2 to 5 below and the Mohr Circle diagram on Figures 6 to 9.

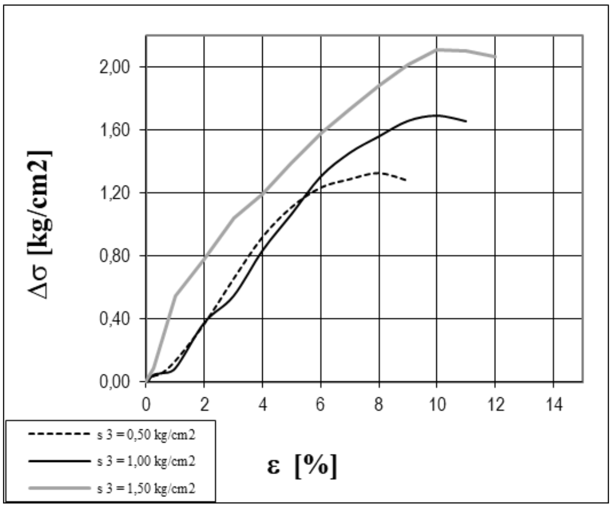

Figure 2 Stress Strain Graphic for Variation 1

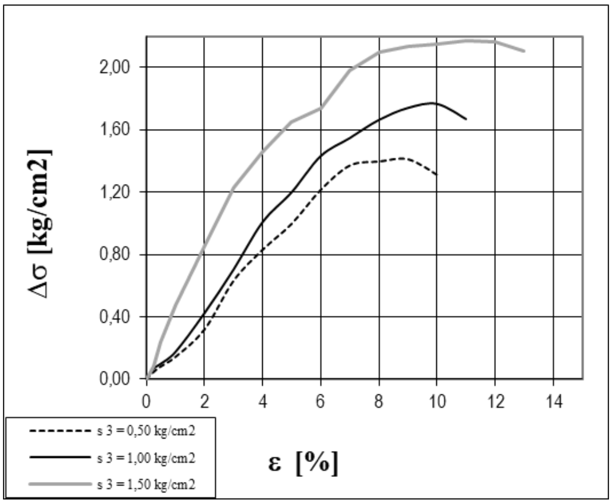

Figure 3 Stress-Strain Graphic for Variation 2

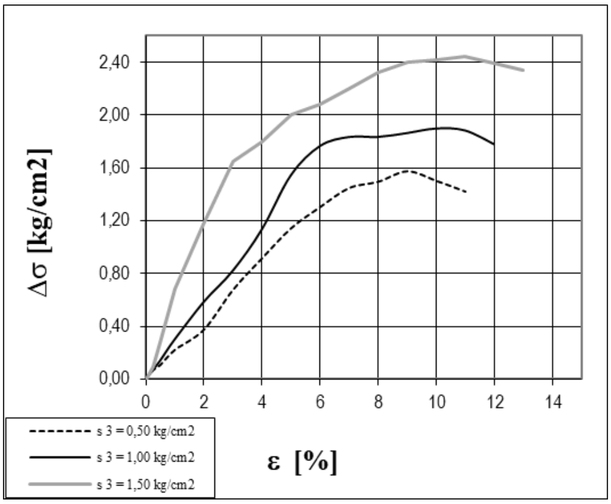

Figure 4 Stress Strain Graphic for Variation 3

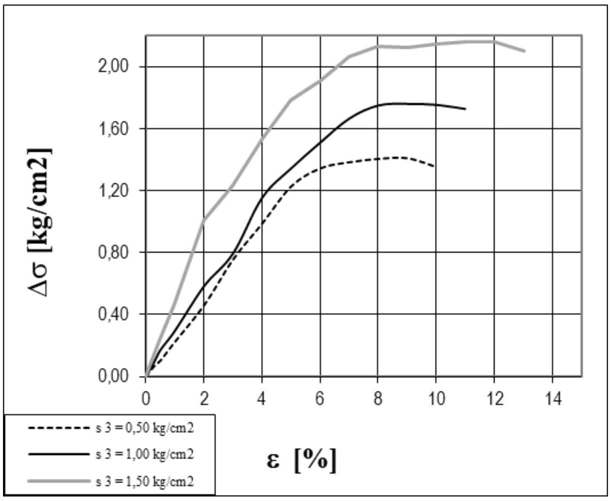

Figure 5 Stress-Strain Graphic for Variation 4

The figure 6 to 9 below describes the result of triaxial data. The mohr circle representing data from each different load applied on the sample. The more loads can show the bigger resistance the soil can hold. The yellow line represents the collapse line. And the soil collapse when the collapse line touches the surface mohr circle. The shear angle is obtained by measuring the angle between the horizontal line and the collapse line. And the value of cohesion is from the point of the lowest collapse line.

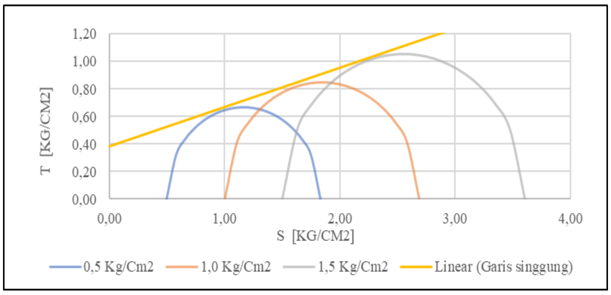

Figure 6 Stress-Strain Graphic for Variation 1

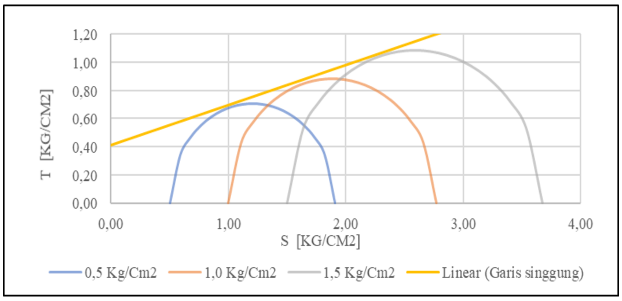

Figure 7 Stress Strain Graphic for Variation 2

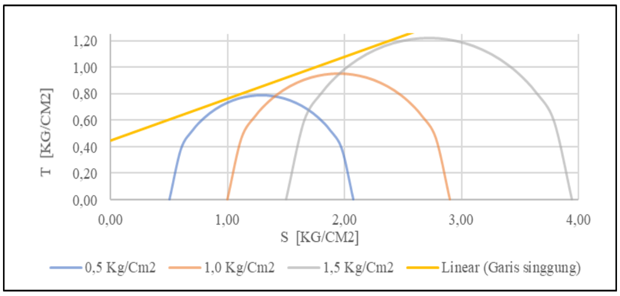

Figure 8 Stress Strain Graphic for Variation 3

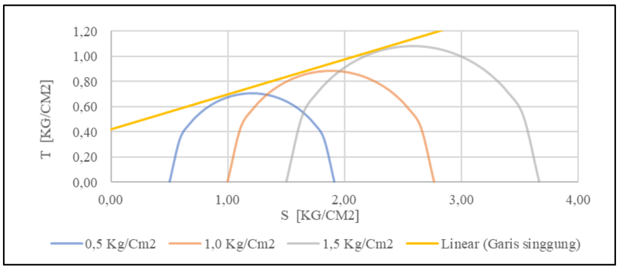

Figure 9 Stress Strain Graphic for Variation 4

4. CONCLUSION AND RECOMMENDATION

1) Gedebage soil has a poor characteristics of soil, proofed by the high PI value, low shear angle and low cohesion.

2) Stabilization can improve poor soil behaviour, in this research it can increase the soil shear strength on the optimum level 5% of Vermiculite and 8% of Emulsified Asphalt (Variation 3).

3) From the testing result, the soft soil has the lowest value of shear strength with φ=17° and c=0,39.

4) The stabilized soil variations are showing increment of shear strength value, but on the last variation of sample (V4) it decreases.

5) The optimum variation is obtained by V3 with φ=20° and c=0,43. It shows the optimum improvement on soil's shear strength parameter from poor clay (φ=17°) to normal clay (φ=20°).

6) More parameters are need to be done in future research to obtain the most precise percentage of stabilization mixture.

7) CBR testing and numeric analysis on software need to be modeled to know if the stabilization succeeds in reducing soil settlement for construction.

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